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## RESEARCH REPORT

# Eye discomfort, headache and back pain among Mayan Guatemalan women taking part in a randomised stove intervention trial

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**Background:** Indoor air pollution (IAP) from combustion of biomass fuels represents a global health problem, estimated to cause 1.6 million premature deaths annually.

**Aims:** RESPIRE (Randomised Exposure Study of Pollution Indoors and Respiratory Effects) Guatemala is the first randomised controlled trial ever performed on health effects from solid fuel use. Its goal is to assess the effect of improved stoves (planchas) on exposure and health outcomes in a rural population reliant on wood fuel.

**Methods:** Questions about symptoms were asked at baseline and periodically after the intervention, to an initial group of 504 women (259 randomly assigned to planchas (mean (standard deviation) age 27.4 (7.2) years) and 245 using traditional open fires (28.1 (7.1) years)). Levels of carbon monoxide (CO) in exhaled breath, a biomarker of recent exposure to air pollution from biomass combustion, were measured at each visit. In addition to reducing IAP levels, the plancha may also have a positive health effect by changing the working posture to an upright position.

**Results:** A high prevalence of eye discomfort, headache and backache was found. The odds of having sore eyes and headache were substantially reduced in the plancha group relative to the group using open fires for the follow-up period (odds ratio (OR) 0.18, 95% confidence interval (CI) 0.11 to 0.29 and (OR) 0.63, 95% CI 0.42 to 0.94, respectively). Median CO in breath among women in the intervention trial was significantly lower than controls.

**Conclusion:** In addition to reducing discomfort for women, tangible improvements in symptoms experienced by a substantial proportion of women may help to gain acceptance and wider use of planchas.

Indoor air pollution (IAP) from domestic biomass combustion is a large global health problem affecting mainly women and young children in rural areas of low-income developing countries. Almost 50% of the world's population still relies on biomass fuel (wood, animal dung or crop wastes) and coal for everyday heating and cooking. In rural areas in many developing countries, the percentage is as high as 90%.<sup>1</sup>

The World Health Organization has recently ranked IAP from solid fuels as the eighth most important risk factor for attributable preventable loss of disability-adjusted life years,<sup>2</sup> causing an estimated 1.6 million premature deaths annually worldwide and with an overall attributable mortality about 50% higher for adult women than for men.<sup>3–4</sup> Of the approximately 1.3 billion people living in poverty, 70% are estimated to be women, many of whom live in female-headed households in rural areas.<sup>5–6</sup> Most of these women are exposed to high levels of smoke pollution for  $\geq 5$  h/day when they cook for the family. Unfortunately, as the trend in global biofuel use over the past 25 years has remained stable or even increased in parts of the developing world, IAP from biomass fuel combustion will remain a substantial public health problem worldwide for many decades to come.<sup>7</sup>

In developing countries, solid fuels are commonly burnt in open fires or in inefficient simple stoves, without appropriate room ventilation. Hence, many health-damaging pollutants are generated, reaching IAP levels much higher than recommended standards. Together, these pollutants are capable of irritating mucous membranes and aggravating respiratory diseases, reducing the resistance to infection and increasing the risk of cancer.<sup>1–8–9</sup> There is consistent evidence for the association

between IAP and health outcomes such as acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease and lung cancer, and tentative evidence for associations with asthma, cataracts, adverse pregnancy outcomes and tuberculosis.<sup>1–10</sup> Smoke (particulates) and sulphur dioxide cause eye irritation and carbon monoxide (CO) causes headache,<sup>11</sup> but little quantitative evidence is available for these outcomes and their association with IAP. The possible health effect of improved stoves that reduces back strain by changing the working posture to the upright position has not been investigated. These three symptoms may represent an important burden in this population of women, who, apart from taking care of the children and cooking food, are responsible for energy and water provision and other essential activities, such as agriculture and animal care.

RESPIRE (Randomised Exposure Study of Pollution Indoors and Respiratory Effects) Guatemala<sup>12</sup> is the first randomised controlled trial ever performed on health effects from solid fuel use. The study aims to evaluate the potential for improving health of an indigenous population in a low-income developing country by researching the consequences of reducing IAP, focusing on ALRI in young children. These results and those related to women's lung health will be presented elsewhere. In households with open woodfires, new chimney woodstoves

**Abbreviations:** ALRI, acute lower respiratory infections; BHeQ, Baseline Health Questionnaire; BHS, Baseline Health Survey; IAP, indoor air pollution; PM<sub>2.5</sub>, particulate matter of aerodynamic diameter  $< 2.5$   $\mu$ m; RESPIRE, Randomised Exposure Study of Pollution Indoors and Respiratory Effects

(planchas) were installed to reduce IAP. Extensive measurements of exposure were undertaken, and health effects in children and women followed up.<sup>13</sup> Broad pilot work was carried out to ensure the feasibility of the methods with regard to intervention, exposure and assessment of health outcomes. The trial itself started in October 2002 and ended in December 2004.

With a randomised intervention design, we examine whether reducing IAP with new stoves (planchas), as indicated by CO in breath, diminishes the burden from eye discomfort and headache among poor rural women in Guatemala. We also investigate the possible benefit of the plancha by changing the working posture to the upright position. Marked improvement in such symptoms may represent one of the more immediate positive aspects of the stove experienced by women, and contribute substantially to acceptability and hence opportunities for wider dissemination.

## PARTICIPANTS AND METHODS

### Population

The study was conducted in a poor, rural indigenous Mayan-Indian community living in San Marcos district in the western highlands of Guatemala (altitude 2700–3000 m). The main language is Mam, and many women speak little Spanish. Illiteracy is common, especially among women. Households in this community are dependent on wood fuel.<sup>14</sup> Smoking is uncommon among Mam women. In homes using open fires, 24-h average levels of particulate matter of aerodynamic diameter  $<25\mu$  (PM<sub>2.5</sub>), the most health-damaging component of smoke pollution, are in the range 600–1000  $\mu\text{g}/\text{m}^3$ , about 10–20 times the United States Environmental Protection Agency (USEPA) guideline level.<sup>15</sup> Women in this area spend, on average, 5 h a day in a room with a lit fire.<sup>16</sup> In addition, most of the Mam women use the “temascal”, a local sauna heated by a wood fire in poorly ventilated conditions. Extremely high levels of wood smoke can be reached inside these temascals.<sup>17</sup>

### Sampling, randomisation and intervention

After a census study in the district, every household using an open wood fire with a child aged up to 4 months (index child) or a pregnant woman (index child not yet born) were invited to participate in the study. In total, 535 households were recruited. The households were followed up until the index child reached 18 months of age. Sample size was determined for the primary outcomes (ALRI), requiring 500 children (630 child-years of follow-up) to detect a 20% reduction in an incidence rate of 0.5 episodes/child/year (power = 80%;  $\alpha$  = 5%). This sample size was also calculated to be adequate for the investigation of respiratory and back symptoms in their mothers (power = 80%;  $\alpha$  = 5%).

Thirty women did not consent to participate. One woman, originally assigned to the open fire open firegroup, was excluded because she had a miscarriage and was consequently given a plancha before the assessment of symptoms at baseline. Thus, a total of 504 women took part. Randomisation was carried out after informed consent was obtained. The study biostatistician generated a list of blocked randomised group assignments, which was inaccessible to field personnel. The blocking factor also remained unknown to study investigators and to field personnel until data collection was complete.

The intervention group was offered a plancha, an indigenously designed and constructed stove (figs 1, 2). Its central feature is a thick mild steel plate through which pot-holes of different sizes are cut, and it has a metal chimney that expels the smoke out of the house.<sup>15</sup> Advice and training on its safe, efficient use and maintenance were given. Poorly operating stoves were identified and repaired throughout the project.

Earlier studies showed that reductions in exposure in young children using planchas everyday was around 40%,<sup>16</sup> and pilot work confirmed that the plancha met most cooking and space-heating needs and achieved a sustainable 4–5-fold reduction in kitchen IAP levels.<sup>18</sup> Households using open fires during the study period were offered a plancha when the index child reached 18 months of age, or on earlier retirement owing to miscarriage or death of the child.

The women were recruited in two rounds. In recruitment group A (October–November 2002), 300 households were recruited, of which 153 received a plancha. In recruitment group B (May–June 2003), 204 households were recruited, of which 106 received a plancha. In this recruitment group, health conditions were assessed before the intervention.

### Procedures

The fieldwork took place through home visits by locally recruited, bilingual (Mam and Spanish) fieldworkers. Data forms were checked daily for errors and missing information. Double data entry and cross checking took place at study headquarters on an on going basis. A random sample of data-entry operations was routinely checked against paper versions.

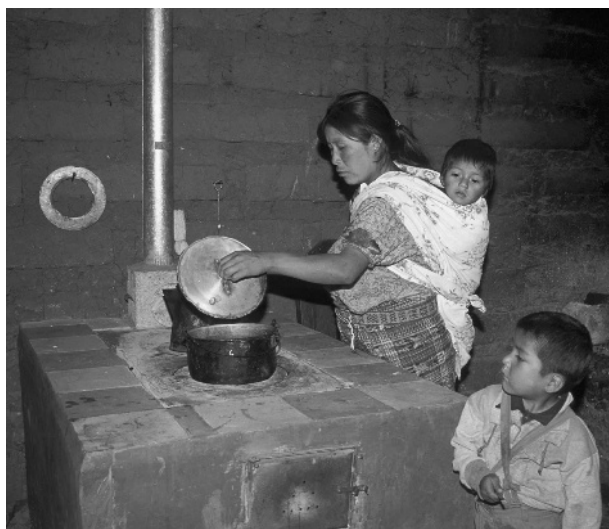
A detailed Baseline Household Survey (BHS) was carried out using interviewer-led questionnaires, enquiring about social, demographic and economic factors. A separate baseline health questionnaire (BHeQ) was conducted, covering respiratory symptoms, eye irritation, headache and backache. These health outcomes were reassessed every 6 months until the woman had finished the study, up to 12 months in recruitment group A and 18 months in recruitment group B.

All the questionnaires were prepared in English, then translated into Spanish and back translated. Afterwards, the Spanish version was translated into Mam, and piloted in focus groups of local women. Symptoms were assessed on the basis of reported experience of sore eyes, headache and back pain during the previous month. The frequency and severity of symptoms were reported.

The BHS was carried out before the stoves were installed in both recruitment groups. Although the initial plan was also to assess health outcomes in all the participants before installation of the planchas, unexpected overload during the initial phase of



Figure 1 Traditional open fire.



**Figure 2** Plancha stove.

the study made it necessary to delay the BHeQ in recruitment group A by a month. Thus, baseline information on symptoms was only available for recruitment group B.

Levels of CO in exhaled breath of the mothers were measured at baseline and follow-up assessments with a Micro Medical Micro CO monitor following standard operating procedures. CO is a biomarker of recent exposure to air pollution from biomass combustion.<sup>19</sup>

### Statistical methods

First, we checked that background characteristics (for all the participants) and symptoms (for recruitment group B) were similar for the plancha and open fire groups.

Potential risk factors (age, pregnancy, passive smoking, house type and having a native steam bath (temascal) at home) that could be associated with the symptoms were determined by univariate analyses at baseline. If significant, these variables were included in a logistic regression model.

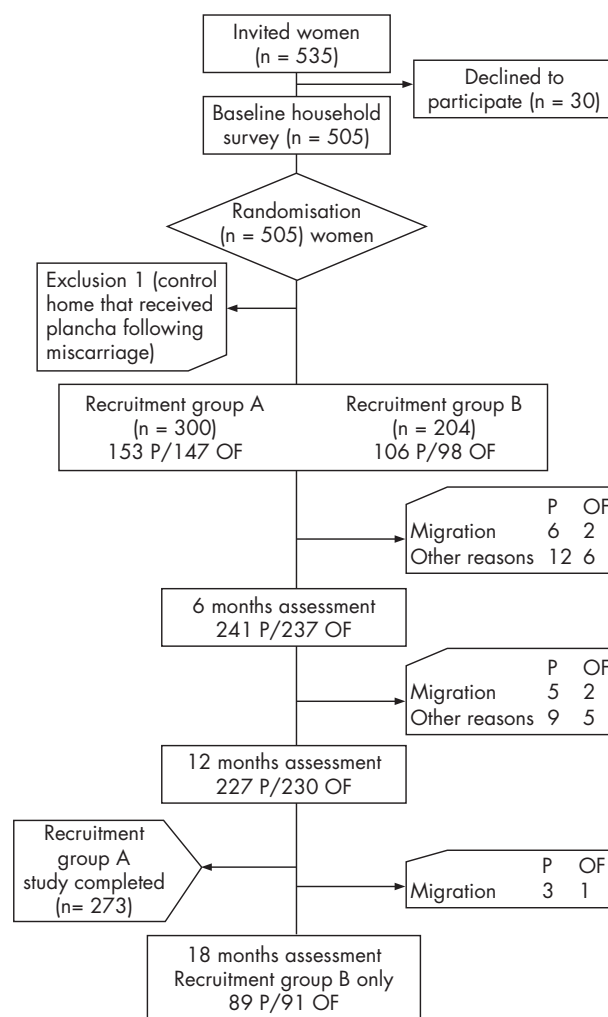
Cross-sectional analyses for the 6, 12 and 18-month follow-up assessments were conducted checking for significant differences between plancha and open fire groups. The Mann-Whitney U test was used to compare CO levels from plancha and open fire groups.

Finally, differences in symptoms between women using plancha and open fire and a possible change over time were estimated in logistic random intercept models. Subsequent observations of the same household were treated as a random effect, and the plancha was treated as a fixed effect. Analyses were conducted with Stata software V.8.

### RESULTS

From 504 women starting the study, the number decreased to 478 (94.8%) at 6 months and 457 (90.7%) at 12 months; recruitment group A had then completed the study after 12 months of assessment. Assessment at 18 months in recruitment group B was carried out in 180 women after a further four women were lost to follow-up. The main reason for withdrawal from the study was migration (fig 3).

The principal background characteristics, including the regular reported presence of symptoms while cooking (assessed at BHS) and the prevalence of symptoms and median CO in exhaled breath at baseline (assessed at BHeQ), are presented separately for recruitment group A and B (table 1). No significant differences were found between households that



**Figure 3** Flowchart showing the exclusions from this study. OF, open fire; P, plancha.

later were divided into those using planchas and open fire. Thus, we found no indication of imbalance in the randomisation. All three symptoms were highly prevalent in this population: approximately half the women reporting symptoms in the past month and more than a quarter reporting that these symptoms bothered them everyday. Reasons for having backache at baseline included washing (55.3%), cooking (29.1%) and carrying wood (18.8%). All symptoms increased significantly with age, but there were no significant associations with pregnancy or other potential risk factors.

Table 2 presents cross-sectional comparisons of data at follow-up surveys.

Median CO in exhaled breath was significantly reduced in the plancha group at all follow-up periods, declining from around 9 ppm at baseline to 5 ppm 18 months after installation of planchas. The proportion of women reporting eye irritation was significantly lower in the plancha group at all follow-up periods. The prevalence of reported headache was also lower for women in households with planchas, but these differences were only significant at 18 months (odds ratio (OR) 2.43, 95% confidence interval (CI) 1.30 to 4.52).

There were no significant differences in prevalence of backache between plancha and open fire groups. However, there was a reduction in both groups from >60% of the women reporting back pain at baseline to <30% at the end of the study.



**Table 1** Baseline characteristics of plancha and open fire groups.

	Recruitment group A (300)		Recruitment group B (204)	
	Plancha	Open fire	Plancha	Open fire
Number of women	153	147	106	98
Baseline household survey (BHS)				
Characteristics of the women				
Mean (SD) age (years)	27.7 (7.2)	28.3 (7.3)	26.9 (7.3)	27.9 (6.8)
Pregnant (%)	13 (8.5)	11 (7.5)	73 (68.9)	65 (66.3)
Mean number (SD) of children <12 years	3.7 (1.7)	3.8 (1.7)	3.6 (1.8)	3.8 (1.6)
Ever smoked (%)	1 (0.7)	1 (0.7)	0	0
Household characteristics				
Family member smoke inside (%)	32 (20.9)	42 (28.6)	20 (18.9)	24 (24.5)
Mean number (SD) cigarettes smoked by husband	1.04 (0.2)	1.06 (0.2)	1.20 (0.4)	1.05 (0.2)
Have temascal * (%)	124 (81.0)	115 (78.2)	101 (95.3)	91 (92.9)
Temascal > once a week (%)	55 (35.9)	55 (37.4)	45 (42.4)	41 (41.8)
Kitchen separate from room (%)	128 (83.7)	126 (85.7)	87 (82.1)	85 (86.7)
Economic indicators				
Owens TV (%)	28 (18.3)	25 (17.0)	25 (23.6)	18 (18.4)
Owens bicycle (%)	29 (19.0)	30 (20.4)	30 (28.3)	21 (21.4)
Have pigs (%)	107 (69.9)	102 (69.4)	62 (58.5)	60 (61.2)
Symptoms from cooking at first survey				
Eyes always irritated† (%)	101 (66.0)	96 (65.3)	59 (55.7)	54 (55.1)
Headache always‡ (%)	53 (34.6)	43 (29.3)	37 (34.9)	32 (32.7)
Back pain always§ (%)	22 (14.4)	31 (21.1)	31 (29.2)	29 (29.6)
Baseline study of health outcomes (BHeQ)				
Sore eyes last month (%)¶	—	—	57 (53.8)	51 (52.0)
Frequency of sore eyes	—	—	17 (16.0)	19 (19.4)
Up to most days a week	—	—	40 (37.7)	32 (32.6)
Every day	—	—	—	—
Headaches past month (%)¶	—	—	79 (74.5)	68 (69.4)
Frequency of headaches	—	—	47 (44.3)	40 (40.8)
Up to most days a week	—	—	31 (32.9)	28 (28.6)
Every day	—	—	—	—
Intensity of the headache	—	—	62 (58.5)	51 (52.0)
Mild/average	—	—	17 (16.0)	17 (17.3)
Strong	—	—	—	—
Back pain last month (%)¶	—	—	66 (62.3)	61 (62.2)
Frequency of back pain	—	—	32 (30.2)	36 (36.7)
Up to most days a week	—	—	33 (31.1)	25 (25.5)
Every day	—	—	—	—
Median CO in exhaled breath (ppm)**	—	—	8.5	9.0

\*Local sauna

†When you are cooking, do your eyes get irritated?

‡When you are cooking or immediately after, do you get a headache? §When you are cooking or immediately after, does your back hurt?

¶Percentage of the total number of women.

\*\*Median of mean carbon monoxide values in breath values from two best readings of three blows.

Using logistic random intercept models for all three symptoms, the plancha seemed to have a protective effect. There was also an overall reduction in symptoms over time independent of intervention (table 3). The odds of having sore eyes was substantially reduced in the plancha group relative to the group with open fire for the follow-up period as a whole. There was also an overall reduction in eye discomfort over time from 6 to 18 months independent of intervention. For sore eyes we also found that the effect of the plancha increased from 6 to 18 months with a 0.49-fold drop in the odds ratio for each 6 months period (95% CI = 0.28–0.83). There was also a decrease in reported headaches in the plancha group relative to the open fire group. The odds was reduced over time (6 to 12 and 18 months) independent of intervention, but the effect of the intervention did not change over time. The prevalence of backache was not significantly reduced by the intervention. There was an overall reduction in reported back pain over

time in the follow-up period, however, independent of the intervention.

The same analyses were performed using only data from 12 and 18 month assessments. The OR for all three symptoms were lower, showing an improving effect of the plancha over time (OR (95% CI) 0.10 (0.05 to 0.22) for eye discomfort, 0.55 (0.32 to 0.93) for headache and 0.73 (0.37 to 1.47) for backache). There was no reduction in symptoms over time independent of intervention when analysing the last two assessments.

## DISCUSSION

Our study confirmed that the use of the plancha in this population significantly reduced exposure to IAP, as indicated by CO in breath, and the prevalence of sore eyes and headache over an 18-month period. The prevalence of back pain was non-significantly reduced.

**Table 2** Symptoms during the past month and carbon monoxide in exhaled breath; cross-sectional analyses between plancha and open fire groups at follow-up

	6 months	12 months	18 months
	n (%)	n (%)	n (%)
Women, n	470 (100)	456 (100)	180 (100)
Plancha	236 (50.2)	227 (49.8)	89 (49.4)
Open fire	234 (49.8)	229 (50.2)	91 (50.6)
Sore eyes in past month, n (%)			
Plancha	48 (20.3*)	19 (8.4*)	7 (7.9*)
Open fire	92 (39.3)	79 (34.5)	31 (34.1)
Headache in past month, n (%)			
Plancha	108 (45.8)	86 (37.9)	24 (27.0†)
Open fire	121 (51.7)	103 (45.0)	43 (47.3)
Back pain in past month, n (%)			
Plancha	74 (31.4)	51 (22.5)	16 (18.0)
Open fire	74 (31.6)	56 (24.5)	23 (25.3)
Median CO <sub>s</sub> in exhaled breath (ppm)			
Plancha	5.0*	5.0*	5.0*
Open fire	7.0	7.0	7.0

Significant difference between intervention and control groups: \* $p=0.0005$ , † $p=0.005$ .

§Median of mean carbon monoxide values from two best readings of three blows. The Mann-Whitney U test was used for testing the significance of differences.

Although not as marked as in the intervention group, a notable constant in our results was the decline of exposure and symptoms in the open fire group. This could be partially explained by fatigue with answering the survey questions, but this explanation cannot account for the reduction in CO in exhaled breath in this group. In previous studies, the plancha showed an 85% reduction in 24-h mean kitchen PM<sub>3.5</sub> levels compared with the open fire during an 8-month period.<sup>15 17</sup> The reduction in exhaled CO in the plancha group in our study was just above 40%, whereas there was a 25% reduction in the open fire group that seemed to be stable over the 18-month period. Explanations for these findings might include behaviour change among homes with open fire because of greater awareness of IAP and health. Additional exposure assessments using different methods were carried out and will be available for reporting at a later date.<sup>13</sup>

Another source of pollution that will have contributed to overall exposure was the temascal, which is used as the primary bathing and purifying method. Exposure among temascal users in the study population has been assessed, finding some of the highest PM<sub>2.5</sub> levels ever measured.<sup>17</sup> As the use of the temascal was balanced in plancha and open fire groups, the temascal is not a confounder in our study. Further investigation of these exposures, along with the development of a culturally appropriate, affordable cleaner-burning temascal fire is planned.

Our findings are in accordance with a previous study of IAP and sore eyes conducted by Ellegård,<sup>11</sup> who found that tears while cooking were strongly correlated with IAP. Indeed, this is an important corroboration, as the exposure in our study was assessed in all women (compared with 20% in Ellegård's study). A later cross-sectional study confirmed the association between exposure to wood smoke and eye symptoms,<sup>20</sup> although the authors recognise the problems of confounding in such a study. Our randomised study design overcomes many of the problems of residual confounding.

**Table 3** Odds ratio and 95% confidence intervals from longitudinal analyses for the period 6–18 months after the intervention for sore eyes, headache and back pain

	OR (95% CI)
Sore eyes in past month	
Plancha/open fire*	0.18 (0.11 to 0.29)
Time†	0.63 (0.50 to 0.82)
Headache in past month	
Plancha/open fire*	0.63 (0.42 to 0.94)
Time†	0.69 (0.55 to 0.85)
Back pain in past month	
Plancha/open fire*	0.85 (0.52 to 1.39)
Time†	0.63 (0.49 to 0.81)

\*Main effect of intervention measured as odds ratio of having a symptom between the plancha and open fire groups.

†Change of odds over time per 6 months during follow-up for each symptom independent of intervention.

Headache is known to be a short-term effect of exposure to CO.<sup>21</sup> However, no literature could be identified investigating the relationship between headache and IAP from woodstoves.

Backache was measured in this study with the hypothesis that symptoms would decline after installation of the plancha owing to the ergonomically improved position when cooking. The possibility of moderate saving of wood could also be a reason for reducing the prevalence of this symptom, as there are women who collect wood and carry it home on their backs. As the percentages of pregnant women declined with time in our population, we should interpret the reduction of reported backache over time independent of the intervention in the longitudinal analysis with caution, as approximately 50% of all women experience back pain during pregnancy.<sup>22</sup>

The general finding that the effect of the plancha tends to increase over time is also notable. As eye irritation and headache might be expected to respond within days or weeks to reduced exposure, this may represent a long-term behavioural adaptation on the part of the women. A detailed qualitative investigation into experience with the plancha has recently been carried out and may shed further light on these issues.

### Limitations of the study

Conducting fieldwork in developing countries is challenging. Unforeseen problems and delays are likely to occur, and there is often need of ad hoc changes during the process. Hence, although the local team worked as well as possible, one of the baseline questionnaires could not be performed in recruitment group A before the planchas were taken into use. Although our study does not have baseline data on the main outcome measures for recruitment group A, we do have pre-intervention data for the whole sample on many background characteristics, including symptoms associated with cooking. Randomisation with regard to many of these key factors in both recruitment groups and to symptoms in recruitment group B showed that the plancha and the open fire groups were balanced.

Our study is based on reported symptoms and not on outcomes obtained by medical certification or diagnostic tests. However, focus interviews to check women's understanding of symptoms before the development of the questionnaires did not detect any difficulty with regard to the terms sore eyes, headache or back pain.

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### What this paper adds

- The odds of having sore eyes was substantially decreased when reducing IAP with an improved stove (plancha) compared with a group using open fire.
- There was also a decrease in reported headaches in the plancha group relative to the open fire group.
- There was an overall reduction in reported back pain over time in the follow-up period, however, independent of the intervention.
- The improvement in symptoms identified may represent one of the more immediate positive aspects of the stove experienced by women, and contributes to acceptability and dissemination of the plancha in this female population.

### What is already known

- Indoor air pollution from combustion of biomass fuels represents a global health problem, estimated to cause 1.6 million premature deaths annually, especially among women and children.
- An improved stove (plancha) had shown an 85% reduction in 24-h mean kitchen PM<sub>3.5</sub> levels compared with open fires during an 8-month period.
- The occurrence of tears while cooking is a useful indicator of exposure to pollution from smoky cooking fuels.

### Policy implications

Women in this population have a long tradition of using open fires that it is not easy to change. The improvement in quality of life through the reduction of short-term symptoms on a regular basis is likely to be important in promoting the demand and use of planchas.

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Competing interest: None.

The study was approved by the respective research ethics committees in Berkeley, Guatemala, Liverpool and Bergen. No adverse events were assessed.

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